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Carbon Market: Systematic risk and Expectations of Returns

—on the comparison analysis of the CDM and EU ETS

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Abstract: The paper uses Capital Asset Pricing Model (CAPM) to analyze the market risk in European Union Emission Trading System (EU ETS) and Clean Development Mechanisms (CDM) and Zipf analysis technology to analyze the carbon price volatility in different expectations of returns in the two markets. The results show that the systematic risk of the EU ETS market is at around 0.07%, but CDM market is clearly divided into two stages, the systematic risk of the futures contracts in the previous stage (DEC09-DEC12) is less than EUETS market, but systematic risk of the futures contracts that entered into the market is greater than the EUETS market and has a higher market sensitivity. But on the unsystematic risk, the CDM market is always greater than the EU ETS market. Abnormal returns in the two carbon markets are both lower than 0.02%, but CDM is higher. The probability of price down is higher than that of price up. Carbon price is affected by market mechanism and the external factor (economic crisis and environmental policies) in the low expectations of returns, but in the high expectations of returns, compared with the CDM market, the carbon price change in EU ETS market is more instable and higher risky.

Key words: European Union Emission Trading System (EU ETS); Clean Development Mechanisms (CDM); Systematic Risk; Expectations of Returns

1. Introduction

Carbon market is a market-based mechanism that used to reduce the global greenhouse gas emissions and global carbon dioxide emissions. The United Nations Intergovernmental Panel on Climate Change, though experiencing tough negotiations, established the “United Nations Framework Convention on Climate Change” (UNFCCC) on 9th May, 1992. After this Convention, the Kyoto Protocol, initially adopted in 1997 and entered into force in 2005, formulates the regular obligations of developed countries in emission reduction. In addition, it also provides three flexibility mechanisms which are Joint Implementation (JI) (implemented among developed countries involving emission reduction), the Clean

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Development Mechanism (CDM) (implemented in developing countries with the capital and technical helps of developed countries), and International Emissions Trading (IET) (in market perspective). These flexibility mechanisms established by Kyoto Protocol thus contribute to the generation of the international carbon emissions trading market.

The global carbon market can be divided into two categories according to the trading mechanisms. One is the Cap-and Trade which is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants (eg. EUA transaction of the EU emissions trading system). Another one is Baseline and Credit program which means polluters that are not under an aggregate cap can create permits or credits by reducing their emissions below a baseline level of emissions. Such credits can be purchased by polluters that have a regulatory limit (eg. CERs of CDM and ERU of JI).

One of the two markets analyzed in this study is the EU Emissions Trading Scheme (EU ETS) whose market value amounted to \$119.8 billion in 2010, dominantly accounting for 84.43% of the total carbon market. Another CDM market, with the transactions volume of \$18.3 billion, is the second largest market. It is worth noting that these two markets are usually not independent of each other. In November 2004, the European Union adopted legislation, known as the Linking Directive, regulating the joint of EU ETS and Kyoto Protocol. On 1st January 2005, the European Union also regulated the admission of CDM credits (CERs) into the EU's greenhouse gas Emissions Trading Scheme (ETS). It is to say, allow enterprises in the EU emissions trading system to meet their emission reduction obligations with the credits from the project mechanism One unit of EUA is equal to one unit of CER. However, the number of CDM emission reduction credits assigned to each member is limited since the second phase of EU ETS and this situation will be more serious in the third phase of EU ETS. It is estimated that the upper limit of CDM emission reduction credits is about 13.4% of the total EU EUA.

Considering the difference between CDM and EU ETS market in market share and operating mechanism, a comparison analysis based on the CDM and EU ETS market is necessary to learn the characteristics of carbon market fully and systematically. What's more, the study of CDM market characteristics is meaningful for China since most of the developing countries are involving program-based carbon emissions trading market. Though many researches, at home or abroad, referred and studied these two markets respectively, there are fewer researches about the quantitative analysis of the CDM market and the comparison between these two markets. With these concerns as motivation, this study seeks to provide a clear standpoint about the comparison between CDM and EUETS markets in systemic risks and expected return perspective as the complement of prior research. Therefore, this study will help us deepen the understanding of the systemic risks and expected return in CDM market and thus know the characteristics of carbon market well.

2. Literature review

A lot of foreign literatures have researched the carbon allowance-based trading market, which includes the design of carbon market mechanisms and price liquidity in carbon market. As for the design of carbon market mechanisms, Cramton and Kerr (2002) asserted that an auction of carbon permits is the best way to achieve carbon caps set by international negotiation to limit global climate change and government should conduct quarterly auctions rather than give the carbon permits away for free by grandfathering. Dallas (2001) compared the cost-effectiveness and distributional effects of a revenue-raising auction, grandfathering, and a generation performance standard as alternative approaches for distributing carbon emission allowances in the electricity sector by using Haiku electricity market model. He found that the auction is roughly one-half the societal cost of the other approaches and grandfathering is the best for producers. He also discovered that the generation performance standard yields the lowest electricity price but highest natural gas price. For the carbon market price fluctuations, most of the researches explored the relationship between carbon price and other energies. For example, Alberola（2008）presented two structural changes and characterized the daily price fundamentals of European Union Allowances (EUA) traded from 2005 to 2007 by introducing dummy variables. The results showed that EUA spot prices react not only to energy prices with forecast errors, but also to unanticipated temperatures changes during colder events. Chevallier (2009) examined the empirical relationship between the returns on carbon futures and changes in macroeconomic conditions by testing with different types of GARCH models. He found that EUETS， as a special commodity market, is affected by the allowance supply fixed by the European Commission and power demand arising from electric operators. Until now, only a few researches studied carbon price liquidity. For example, Benz (2009) established a carbon price return model for EU ETS by Markov process and AR-GRACH to study the liquidity and price discovery.

From the approach of program-based carbon transaction, Ellerman, Jacoby and Decaux (1998) used the marginal abatement curves (MACs) of MIT’s Emissions Prediction and Policy Assessment (EPPA) model to analyze the roles of developing countries in emissions reduction. They indicated that the emissions reduction costs in developed countries can be reduced through CDM mechanism.

In China, the researches of EU ETS and CDM market are currently independent of each other. Most of the CDM market researches focus on the risk analysis and response strategies in specific project implementation. Zheng Shuang (2006) analyzed different risks in development, registration and implementation stages of CDM project and proposed appropriate control measures accordingly. Zhao Meng and Kang Yanbin (2011) analyzed the dynamic CDM projects development in China and found some problems in CDM operation and management, including the lack of certification agency, the confusion of intermediary market and the low transfer price. They also put forward some relevant proposals to solve the problems mentioned above. As for the knowledge of EU ETS, price liquidity and risk measurement were explored widely in China. Zhang Yuejun and Wei Yiming (2011) investigated the operating characteristics of the EU ETS carbon futures market using mean reversion theory, GED-GARCH model and the VAR approach and found that the EU ETS’s price, revenue, market volatility and the change of market risk are not subject to the mean reversion process, showing unpredictable characteristics. Besides, Feng Zhenhua and Wei Yiming (2011) exerted CAPM model and Zipf method to measure and analyze the market risk and expected return of EU ETS respectively.

Since the research of EU ETS and CDM markets has begun, attention has been given to their independent effect and the EU ETS market effect has been studied a lot by previous researches. However, none of literatures conduct a comparison analysis between these two markets and most of the researches are focus on qualitative analysis rather than quantitative analysis when exploring CDM market characteristics.

On the basis of the prior researches, in this study we will comparatively analyze the market risk and expected return of the EU ETS and CDM market using CAPM and Zipt methodology in order to have a better understanding of carbon market characteristics.

3. Research methodology

3.1 Futures contracts’ rate of return model based on CAPM

The return rate of futures contract in carbon market

$$r_i = \alpha_i + \beta_i r_m + \xi_i \qquad (1)$$

In this formula , $r_i$is the rate of return for a single futures I, $r_i = lnP_i - lnP_{i-1}$， P is the price of carbon;

r_m is the return rate level of the whole market; β_i shows the systematic risk level of carbon futures contract i; α_i means a part of expected rate of return which deducts the standard market level.

Thus, we can conclude from formula (1):

$$\sigma_i^2 = \beta_i^2 \sigma_m^2 + \sigma^2(\xi_i) \quad (2)$$

In this formula, $\beta_i^2 \sigma_m^2$ is the systematic risk, showing the uncertainty of the association between carbon futures contract i and carbon market; $\sigma^2(\xi_i)$ is the non-systematic risk, which reflects the uncertainty caused by the internal factors of the carbon futures contract i.

3.2 Dynamic carbon price model based on Zipf method

We set the $\mathrm{P(t)} = \{p(t_1), p(t_2), \dots, p(t_n)\}$, $p(t_i) = p_i(i = 1,2, \dots, n)$ as carbon price series; $r_i(\tau)$ is the rate of return on day i in a given time scale τ.

$$r_i(\tau) = \frac{p(t_i+\tau)-p(t_i)}{p(t_i)}, \quad \mathrm{i} = 1,2, \dots, \mathrm{n}-\tau \quad (3)$$

Therefore, we can obtain the carbon futures contract rate of return series $\mathrm{r}(\tau) = \{r_1(\tau), r_2(\tau), \dots, r_{n-\tau}(\tau)\}$ in different time scale. The time scale τ =1, 5, 20, 60, 120, 250 correspond to the trading day, week, month, quarter, half year, and years. ε is the threshold of the investor's expected return. Thus, we get a new series $\mathrm{f}_i(\tau, \varepsilon)$:

$$\mathrm{f}_i(\tau, \varepsilon) = \begin{cases} -1, r_i < -\varepsilon \\ 0, -\varepsilon < r_i < \varepsilon \\ 1, r_i > \varepsilon \end{cases} \quad (4)$$

$n_-(\tau, \varepsilon)$, $n_0(\tau, \varepsilon)$, $n_+(\tau, \varepsilon)$represent the times of the series $\mathrm{f}_i(\tau, \varepsilon)$ in decline, unchanged and rise respectively. Then, we get the frequencies of absolute decline, unchanged and rising as:

$$p_-(\tau, \varepsilon) = \frac{n_-(\tau,\varepsilon)}{n-\tau} \quad (5)$$

$$p_0(\tau, \varepsilon) = \frac{n_0(\tau,\varepsilon)}{n-\tau} \quad (6)$$

$$p_+(\tau, \varepsilon) = \frac{n_+(\tau,\varepsilon)}{n-\tau} \quad (7)$$

The frequencies of relative decline and rising are:

$$\phi_-(\tau, \varepsilon) = \frac{n_-(\tau,\varepsilon)}{n_-(\tau,\varepsilon) + n_+(\tau,\varepsilon)} \quad (8)$$

$$\phi_+(\tau, \varepsilon) = \frac{n_+(\tau,\varepsilon)}{n_-(\tau,\varepsilon) + n_+(\tau,\varepsilon)} \quad (9)$$

The investment time scale τ represents investors' different preference for price trends. For example, the investors will prefer a long-term transaction in carbon market when the τ has a big value. ε represents investor's expected return for the carbon market's return rate. The bigger the ε value is, the higher the investor's expected return is.

The traders of carbon market are various and their investment choices are always associated with different time scales and expected return. In market transactions, investors make decisions on the basis of whether the assumed expected return is achieved, indicating that investors' willingness to trade are generated only on the condition that carbon price can achieve their expected return or the risk is acceptable. Meanwhile, transaction costs and market uncertainty can contribute to risks and costs for investors. So, investors are willing to trade when the actual return rate is higher than ε, which reveals a substantial rise in carbon price. When the return rate is equal to ±ε, the carbon price has no substantial change in the perceptions of investors and they will not trade. However, when the rate of return is lower than ε, investors will trade since the loss of carbon price has exceeded the expected maximum loss value. Therefore, ε is a good indicator reflecting investors' mental endurance and market expectation.

4. Data and analysis

4.1. Data Source

The futures contracts data of CDM market and EU ETS market come from the website of European Climate Exchange (ECX). We selected the daily data and used the futures contract category DEC09—DEC14 with the time period from 12th January, 2009 to 1st March, 2012 as our research object.

Table 1: Futures Contract and Contract Term in CDM Market and EU ETS Market

CDM Market		EU ETS Market	
CER Futures Contract	Contract Term	EUA Futures Contract	Contract Term
DEC09	2009-1-12 to 2009-12-14	DEC09	2009-1-12 to 2009-12-14
DEC10	2009-1-12 to 2010-12-20	DEC10	2009-1-12 to 2010-12-20
DEC11	2009-1-12 to 2011-12-19	DEC11	2009-1-12 to 2011-12-19
DEC12	2009-1-12 to 2012-3-1	DEC12	2009-1-12 to 2012-3-1
DEC13	2011-1-24 to 2012-3-1	DEC13	2009-9-29 to 2012-3-1
DEC14	2011-1-24 to 2012-3-1	DEC14	2010-9-28 to 2012-3-1

We select DEC12 contract as the main research object when studying the effects of different return rate and different investment time.

4.2. The analysis of systematic risk and non-systematic risk in carbon market

The results of CDM market and EU ETS market systems were showed in TABLE 2 according to the formula (1) and (2) in the CAPM futures contract return rate model.

Table 2: The β value, Systematic Risk, Non-systematic Risk and Abnormal Returns of Various Carbon Futures Contracts in CDM Market and EU ETS Market

Futures Contract	CDM Market				EUETS Market			
	β	Systematic Risk /%	Non-systematic Risk/%	α /%	β	Systematic Risk /%	Non-systematic Risk /%	α /%

DEC09	0.9613	0.0734	0.0073	0.0060	0.9969	0.1096	0.0017	0.0046
DEC10	1.0496	0.0556	0.0058	0.0100	1.0221	0.0725	0.0024	0.0045
DEC11	1.0251	0.0608	0.0126	0.0031	1.0183	0.0730	0.0022	-0.0013
DEC12	0.9709	0.0616	0.0070	-0.0155	0.9941	0.0767	0.0008	-0.0024
DEC13	0.9615	0.0888	0.0117	-0.0005	0.9816	0.0589	0.0004	-0.0050
DEC14	0.9661	0.0896	0.0214	0.0126	0.9794	0.0757	0.0026	0.0049

The analysis of carbon market β value shows: Firstly, the sensitivity of market price fluctuations was smaller for unexpired futures contracts DEC12—DEC14 than for expired futures contract DEC10、DEC11 in two markets with both of them is lower than the average market risk. The reason behind this phenomenon is: compared to forward contracts, the current transaction is paid more attention by traders and is easily impacted by external events. For example, the market risk of futures contract, which is delivered near Europe debt crisis in 2010, is bigger than that delivered away from this debt crisis. Secondly, the longer the contract term, the smaller the β value is, showing that traders will prefer durable long-term contract no matter in CDM market or in EU ETS market. Thirdly, for expired futures contracts in two markets, the market price sensitivity is bigger in CDM market than that in EU ETS market. While for unexpired futures contracts DEC12—DEC14 in two markets, the market price sensitivity is smaller in CDM market than that in EU ETS market.

The analysis of systematic risk in carbon market shows: First, the systematic risks of early (January 2009) futures contracts DEC09—DEC12 are basically the same, floating up and down around 0.06%. However, for the futures contracts DEC13 and DEC14 which entered into market in January 2011, the systematic risks are relatively large, about 0.09%. The increasing systematic risk is due to the challenges faced by global CERs trading system in 2010. In February 2010, the European debt crisis occurred associated with economic downturn, hindering the industrial production in many Europe countries. The carbon emissions were reduced and the price of CER futures was in a down state. At the end of 2010, Cancun meeting, held in Mexico, didn't reach an agreement for the development of CDM in Kyoto period after 2012, arousing the worried about CDM existence after the first Kyoto commitment period. What's more, the systematic risk of CER futures contract can also be increased by the impact of the factors such as EU's decision about limiting the CDM emission reduction credits in 2013 and the delivery problem in December 2010. Second, the market systematic risk of EU ETS is basically stable at around 0.07%. Factors such as political decision-making, energy prices, the stock market and abnormal weather can lead to a high market systematic risk in EU ETS market. Besides, the early CDM futures contracts DEC09—DEC12, with the help of clear policies, are associated with less uncertainties and less systematic risks than that in EU ETS market. But then the systematic risk is greater in CDM market than that in EU ETS market when faced with policy uncertainty.

We can also conclude from the analysis of non-systematic risk in carbon market that: First, the DEC13 and DEC14 in CDM market have greater non-systematic risks because the overall systematic risk of DEC13 and DEC14 is large, increasing the single contract's non-systematic risk. Second, the non-systematic risks of different futures contracts are almost the same in the same time period in EU ETS market. Third, the non-systematic risk of CDM market is around 0.01% while that risk of EU ETS market is less than 0.003%. Overall, the non-systematic risk of EU ETS market is less than that of CDM market. The reason for a higher non-systematic risk is that CDM is an economic means associated with commercial property which based on the implementation of individual projects. The CERs generated by CDM projects are usually long-term products. However, in many cases the CER transaction contracts are signed in the project development and preparation phase. It is to say that the CER price is fixed at the beginning and trades are likely to suffer the risk of market price fluctuations. If the CER market price increases when delivery, developer will suffer the loss and may abandon the contract and find another buyer. On the contract, if the CER market price decreases when delivery, buyer will suffer the loss and may tear up the contract and find another seller. Besides, CDM project is also likely to involve in operation risk, financial risk and approval risk, with different projects faced with different risks. In sum, CDM market, compared with EU ETS market, has a higher non-systematic risk.

The return rates of futures contracts are nearly equal to the average market return rate in two markets, with abnormal returns less than 0.02%. Therefore, it is difficult for investors to diversify risk and make profit by the means of portfolio contracts regardless of which market. The excessive expected return will be limited in carbon market.

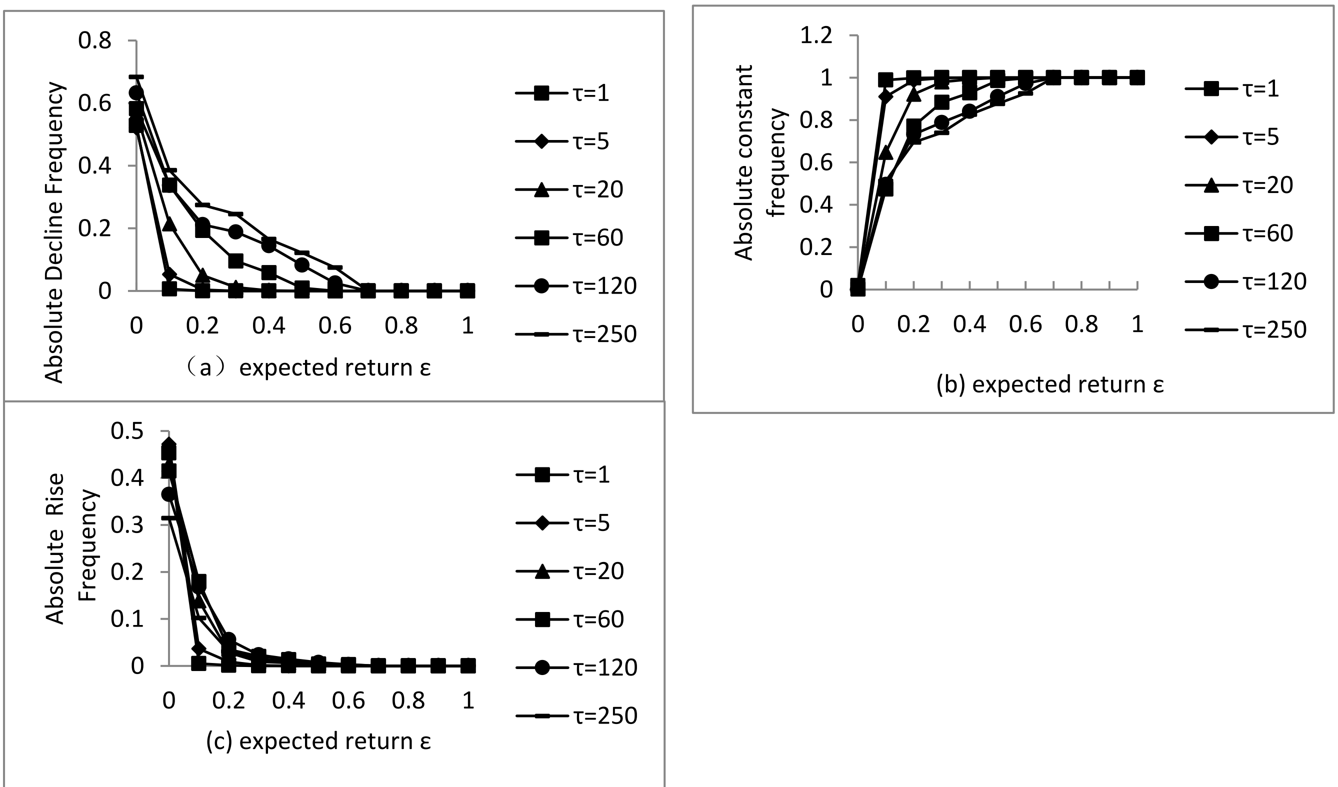
4.3. Empirical analysis of effect of expected return on carbon price based on Zipf method.

Through the analysis above, we know that using futures contract portfolio to diversify risk or make profit in the same market is not a good choice in carbon market. As the transactions subject in carbon market is heterogeneous, different investors have different investment expectations. Next, we will further analyze the effect of different expected return rates on the carbon price volatility and analyze the carbon price changes in high and low expected return situations.

Investors' expectations may distort the carbon price, but this distortion has a deadline --the saturation point. With the growth of expected return, the frequency of rise or fall does not change any more after the saturation point (see FIGURE 1 and FIGURE 2).

The conclusions of the analysis of carbon price volatility associated with different expected return in two markets are listed as follows:

（1）The higher the investors' expected returns are, the more extreme judgments of price trend will be. Take CDM market as an example, the price is random in investors' perceptions when τ=1 and the expected return is lower than 0.1. While when the expected return is higher than 0.1, the probability of price change is close to 0. Through the comparison between figure 1 and figure 2, we find that the expected return saturation point of CDM market is higher than that of EU ETS market, which can also be confirmed in Tabel1.



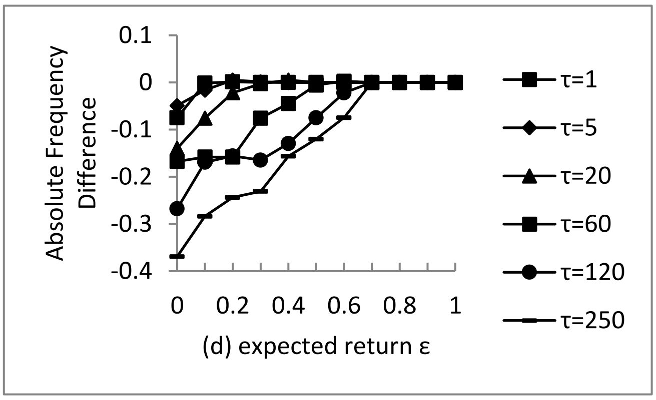


Figure 1 Trend of absolute rise and fall frequency with ε in CDM market

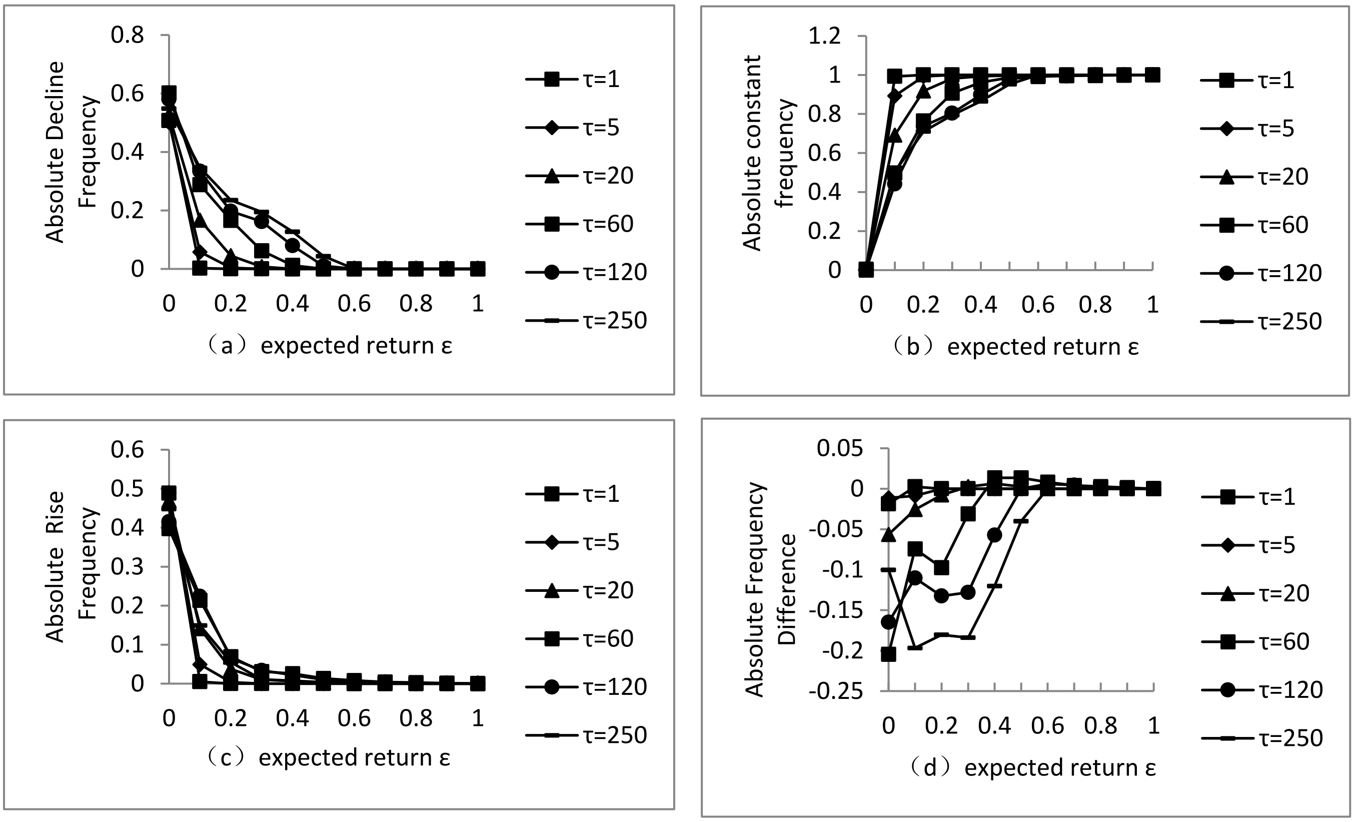


Figure 2 Trend of absolute rise and fall frequency with ε in EU ETS market

（2）Through the comparison of difference in absolute rise and fall frequency (d) in FIGURE 1 and FIGURE 2, we can see that the price change in two markets is asymmetric. Before the saturation, the difference between price rise frequency and price fall frequency is not equal to 0 and price fall frequency is higher than price rise frequency. The down state of carbon price is caused by many uncertainty factors in carbon market expansion, which include global financial crisis began in 2009, European debt crisis associated with economic and production recession and the slow progress of international climate policy negotiations.

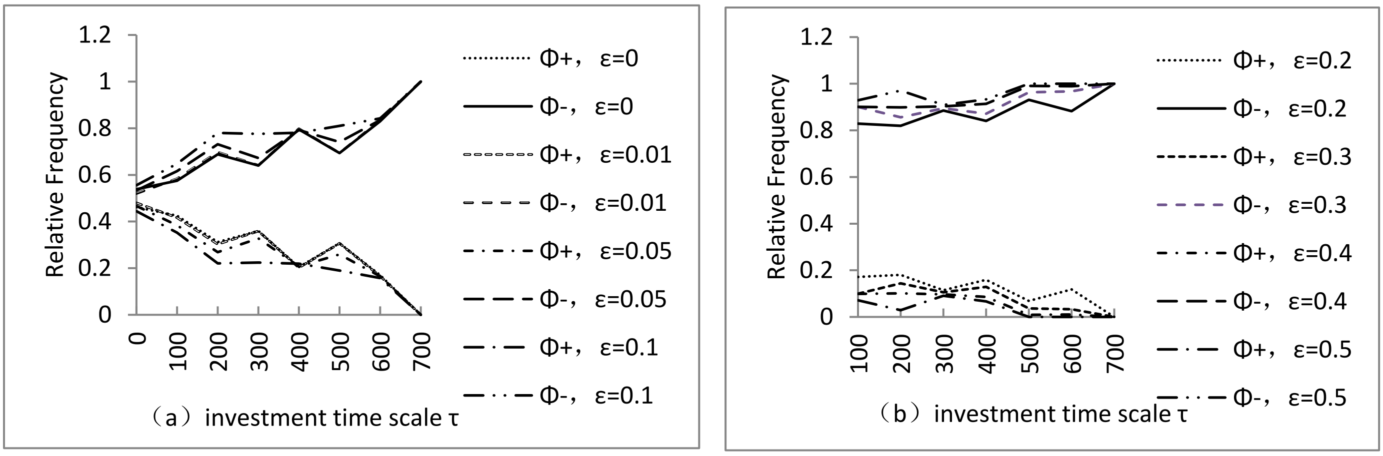


Figure 3.Awareness of investors with different expected returns on the historical price information in CDM market

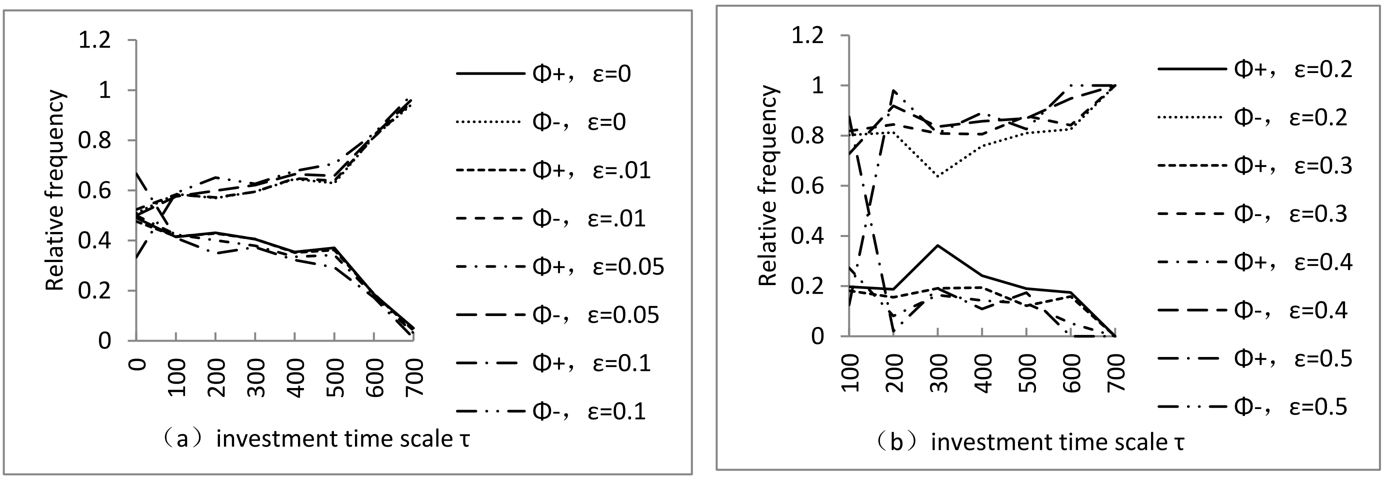


Figure 4. Awareness of investors with different expected returns on the historical price information in EU ETS market

（3）Through the analysis of (a) part in FIGURE 3 and FIGURE 4, we conclude that in the case of low expected return, the bearish probability will gradually increase to 1 and the bullish probability will decrease to 0 with the increase of investment time scale in two markets. It is clear to see the ups and downs of carbon price as well as the changes of relative frequency in two markets. The changes of relative frequency are divided into two stages: ① Market participation stage: carbon price change is relatively slow, with the probability ranged from 0.4 to 0.6. In this case, carbon price is close to random walk and price bullish or bearish is spontaneous as the result of market regulation. ② As the investment time scale becomes large, the relative change frequency will significantly disperse. The long-term investment affected by external factors (eg. economic crisis and environmental policy) is likely to suffer a big fluctuation and associated with bearish probability. In short, considering the difference between the two markets, EU ETS market is easy subject to market regulations while CDM market is easy to be affected by external factors.

（4）Through the analysis of (b) part in FIGURE 3 and FIGURE 4, we find that in the case of high expected return, EU ETS market, compared with CDM market, experiences more disordered price ups and downs. When ε is bigger than 0.2, the relative probability becomes scattered and quickly converges to 1. The probabilities of bearish and bullish are unstable and emerge a big deviation, leading to investment instability. Therefore, in EU ETS market, participants' expected return should not be too high. Unlike EU ETS market, CDM market has relatively stable bullish and bearish probabilities, which is in line with our prior conclusion that the expected return of EU ETS market is less than that of CDM market.

5. Conclusion

This study examines the systematic risks in CDM market and EU ETS market with the help of CAPM model and further analyzes the frequencies of carbon price rise and fall under different expected returns. The results are as follows:

(1) Compared with the expired futures contracts DEC10 and DEC11 in two markets, the unexpired futures contracts DEC12—DEC14 have less sensitivities for market price fluctuations and have lower risks than the market average level. No matter in which market, the longer the contract is, the less sensitive for market price fluctuation that contract is. The β value of expired contract is higher in CDM market than that in EU ETS market; For the unexpired futures contracts DEC12—DEC14 in two markets, the sensitivities of market price fluctuations are lower in CDM market than that in EU ETS market.

(2) The systematic risks of the CDM market futures contracts are divided into two stages: the systematic risks of the CDM futures contracts DEC09—DEC12 which entered into market early are nearly the same, floating around 0.06%; while the systematic risks of contracts DEC13and DEC14, which entered into market in January 2011, are relatively large, about 0.09%. For EU ETS market, the systematic risks are basically stable at around 0.07%. Therefore, in early stage, the systematic risks of CDM futures contracts are less than that of EU ETS futures contracts and this conclusion is reversed in later stage.

(3) The non-systematic risks of CDM market are about 0.01% while that of EU ETS market are less than 0.003%, showing that overall the non-systematic risks of EU ETS market are less than that of CDM market.

(4) The futures contract rate of return in two markets generally flat with the market rate of return with abnormal return less than 0.02%, showing a restriction for investor's expected return.

(5) The price ups and downs in two markets are asymmetric. Before the saturation, the difference between price rise frequency and price fall frequency is not equal to 0 and price fall frequency is higher than price rise frequency. In the case of low expected return, the carbon price is affected by market regulations as well as external factors in both markets. Market regulations have a stronger effect on EU ETS market while CDM market are easy subject to external factors; In the case of high expected return, investors in EU ETS market, compared with investors in CDM market, have more unstable awareness of carbon price fluctuation. So, in EU ETS market, participants' expected return should not be too high.

Based on the conclusions discussed above, we propose the following recommendations:

(1) Generally speaking, the development of CDM market is not optimistic worldwide. The first Kyoto commitment period is approaching and the negotiations on global climate change have not reached an agreement, leading to an unclear prospect of CDM development. What's more, futures contracts which entered into CDM market recently have greater systematic and non-systematic risks than futures contracts entered into EU ETS market. In addition, EU, the largest buyer for carbon credits, has put forward a principle that only use CERs from the least developed countries in new CDM project since 2013. So, CDM market in China is likely to be affected seriously if EU gives up Chinese market. Faced with so many uncertainties in CDM market, China should take measures to avoid CDM project risk when participating in carbon market; In the long run, the development of China carbon market cannot only rely on the CDM market. China should set up its own emission reduction standard as well as trading system and combine them with Chinese current economic model.

(2) Compared with the general futures market, the carbon futures market is still an emerging market associated with low expected returns and relative inactive carbon transactions. So, in order to set up a more mature carbon market and attract more investors, it is necessary to gradually improve the carbon market's access system. Currently, the number of futures contracts available for trading is still insufficient in carbon

market and there is less opportunity for investors to profit, which limit the development of carbon market. Moreover, carbon market, as a special futures market, should also be considered its function in reducing greenhouse gas emissions. As for how to balance the openness and emission reduction effect in carbon market, future research is needed for a further exploration.

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